analytical methods so long as the necessary physical bases are lacking. Neither of the coefficients adopted above is absolutely reliable. Besides, in order to complete the solution of the problem and verify the results of mathematical analysis, we must have at hand the results of simultaneous nocturnal observations of the temperature of the atmosphere at different heights (say, from $x = 0$ to $x = 30$ meters) and of the temperature of the earth's surface and the soil at different depths. We need accurate knowledge of the position of the strata of invariable temperature in the earth and in the atmosphere. As pointed out elsewhere, we must also know more completely the magnitude and variation of the imaginary athermanous surface and of its functional relation to the sidereal heat and the temperature of the upper atmosphere. This paper does not pretend to contribute anything toward the final solution of the problem; but in the present status of our knowledge of the subject, even an approximate analysis may yet prove of importance. This statement is justified by Lord Rayleigh's introductory words in his memoir on the Vibrations of an Atmosphere:[26]

In order to introduce greater precision into our ideas respecting the behavior of the earth's atmosphere, it seems advisable to solve any of the problems that present themselves, even though the search for simplicity may lead us to stray rather far from the actual question.

In preparing the account of this research, I am indebted to many writers, from whose books and memoirs I freely quoted in order to support my views on the subject. I would especially mention Dr. J. Maurer's important memoirs, often mentioned previously. I take the advantage of this opportunity to express my gratitude for valuable criticisms and suggestions, to Prof. R. S. Woodward, now President of the Carnegie Institution, whose masterly command of mathematical analysis in physical inquiry and whose clear and lucid exposition have been the source of inspiration that led me to pursue the study of mathematical physics with great enthusiasm; and to the Editor of the MONTHLY WEATHER REVIEW, under whose kind direction I have been engaged in meteorological research and who proposed the present problem[27] for investigation. I have also to thank Prof. A. Graham Bell, of Washington, D. C., and Dr. L. A. Bauer, the Director of the Department of Terrestrial Magnetism of the Carnegie Institution, for their cordial assistance in many ways.

THE INFLUENCE OF SMALL LAKES ON LOCAL TEMPERATURE CONDITIONS.

By JAMES L. BARTLETT, Observer Weather Bureau. Dated April 25, 1905.

The city of Madison, Wis., is situated between Lakes Mendota and Monona on a strip of land trending northeast and southwest and varying in width from one-half to three-fourths of a mile. Since April, 1883, meteorological observations have been taken at Washburn Observatory, which is located at one end of this strip on a slight ridge overlooking Lake Mendota, the larger of the two lakes; the observatory is 100 feet above and 600 feet distant from this lake. Besides the two lakes mentioned there are several smaller ones in the vicinity, so that within a radius of five miles from the observatory the surface is about one-third water. It would therefore appear to be a very favorable location for observing any appreciable effects that the lakes may have upon the local air temperature.

To obtain an accurate knowledge of these effects it was found necessary to compare the Washburn Observatory temperatures with those of neighboring points which have no lakes in their vicinity. For this purpose the records at the four cooperative observation stations nearest to Madison were selected. These are Harvey, Portage, Beloit, and Dodgeville,

located, respectively, to the east, north, south, and west of Madison and within a radius of 45 miles from the last-named city.

For periods of the same lengths and dates in each case for Madison and for the point under consideration the following temperature data for each calendar month were computed: mean, mean maximum, mean minimum, and mean daily range. Corrections for the differences in the mean annual temperatures of the various places were then applied. Thus, the mean annual temperature at Beloit was found to be 1.3° higher than that at Madison for the period under consideration; this amount was therefore deducted from all of the Beloit data, except the mean daily range. The resulting values were presumed to show the temperature conditions which would exist at Madison were there no lakes in its vicinity. The departures of the Madison temperature data from the corrected data of the other points were then computed and are plotted below. The departures are shown in degrees Fahrenheit and are positive above the zero line, negative below. The curves, reading downward in each case, show the departures, respectively, from the Harvey, Portage, Beloit, and Dodgeville data.

The departure curves of fig. 1 show certain general points of agreement. The mean maximum and mean daily range curves have a negative departure, and the mean minimum a positive departure during nearly all the year in each case. The mean monthly curve has a general negative departure during the first five months and a general positive departure the remainder of the year. The mean minimum reaches its extreme positive departure in August in each case. It is believed that the irregularities of certain of the curves, particularly of those of the mean maximum, are due to local peculiarities of the climate of the various points. Thus, Beloit and Harvey are nearer to, and therefore their temperatures are more under the influence of, Lake Michigan than is that of Madison. Dodgeville is more remote from the great lake and less affected by it. Portage is in the valley of the Wisconsin River, which doubtless has some influence upon local temperature conditions. To eliminate these irregularities as far as possible an average of the departures was plotted for each element of the temperature data, and this may now be considered.

The monthly mean departure curve (fig. 1, No. 19) shows quite clearly the slight influence which the lakes have in retarding the annual increase of temperature in the spring and its decrease in the fall. This seems to be manifested in the spring by a lowering of the maximum or day temperatures, and in the fall chiefly by a raising of the minimum or night temperatures.

The influence of the lakes in preventing the occurrence of killing frosts late in the spring and early in the fall is quite marked, and is indicated by the positive departure of the minimum curve from April to October. The average date of the last spring killing frost at Madison is April 21; the average date for Harvey, which has nearly the same latitude as Madison and is nearer Lake Michigan, during the past thirteen years has been over two weeks later. In the fall killing frosts occur in general two weeks earlier at Harvey than at Madison. It would thus appear that the growing season is considerably lengthened at Madison by the presence of the lakes.

During January and February the lakes are almost invariably thickly coated with ice, and presumably the local exposure then becomes purely continental. That the frozen lakes do exert some control upon the temperature of the overlying air is shown by the fact that the range of temperature at Madison during these months still averages over two degrees less than at points away from the lakes. Also the monthly mean is slightly below the assumed purely continental type at this time, but it is possible that this should not be the case. It seems more reasonable to believe that the whole mean

[26] Phil. Mag., Feb., 1890. Abbe's Mechanics of the Atmosphere, p. 289.
[27] The third and fourth papers on the subject will be published in a subsequent number of the Monthly Weather Review.

monthly departure curve should be raised sufficiently to eliminate the negative departures during January and February, a step which would be equivalent to assuming that the mean annual temperature at Madison is slightly increased by the presence of the lakes. This, however, can not be proved from the data at hand.
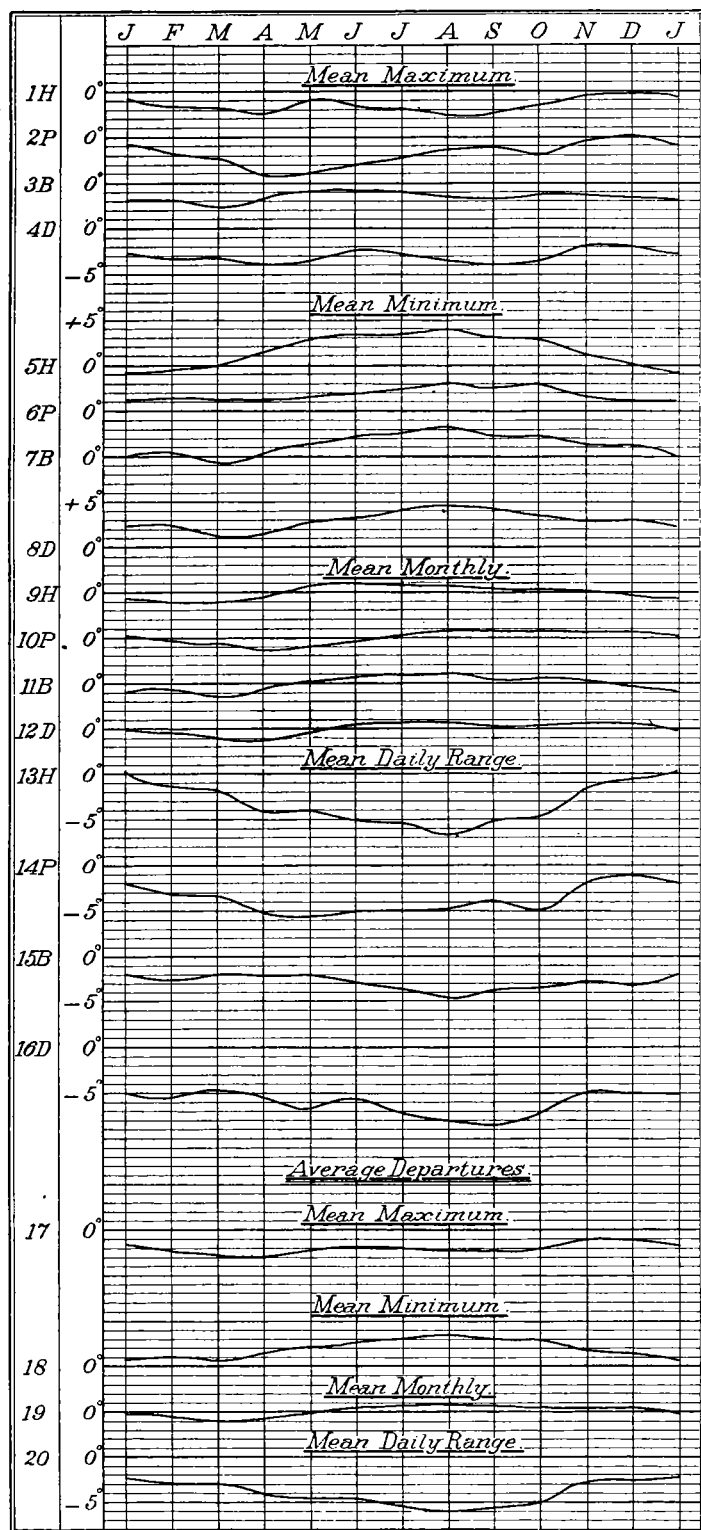

Fig. 1.—Departure curves.

In August the minimum curve reaches its extreme positive departure and the daily range of temperature averages six degrees less than that of neighboring purely continental ex-

posures. Doubtless this is due to the presence of much water vapor in the air over the now well warmed lakes, this vapor absorbing much of the heat radiated from the sun during the day and from the earth at night. The high minimum during August indicates why the vicinities of small lakes during this month are less desirable pleasure resorts than at other seasons of the year.

The most marked tendency of the Madison temperature conditions to return to the purely continental type is shown in the curves from October to November, although the local lakes do not close until about December 21 as a rule. The freezing over of the lakes is usually preceded by several days of cold weather during which the temperature may fall nearly to zero. This cold spell frequently culminates on the day of closing and the succeeding few days are somewhat warmer. No decided change to the strictly continental type appears to occur near the date of closing, although a study of the Madison records for each year shows that the average decrease in temperature from the month preceding this date to the month following is about three degrees more than the normal.

While the exposure at Madison especially favors the influence of the lakes on the observed temperatures, yet it is believed that wherever small lakes are found, the temperature conditions in their vicinity will show departures from the purely continental type of their section much resembling those given above, though not so marked.

THE GREAT INDIAN EARTHQUAKE OF APRIL 4, 1905, AS RECORDED AT THE WEATHER BUREAU.

By CHARLES F. MARVIN, Professor of Meteorology.

The great earthquake that almost entirely destroyed the mountain towns of Dharmsala, Kangra, and Palampier, in northwestern India, causing great loss of life and property over a wide extent of adjacent territory, was very fully recorded at Washington, D. C., on the Bosch-Omori seismograph at the Weather Bureau.

There is very little about the record to suggest that the disturbance was one of unusual character. In fact, we have records of other earthquakes apparently of decidedly greater violence, but whose foci appear to have been remote from populated regions. On this account or for some other reasons the disturbances were not marked by such great disaster and destruction as to draw widespread attention to their occurrence. Consequently our records in these cases have not been correlated with any published accounts of earthquakes.

In the case of the Indian earthquake, the vibratory motion as recorded at Washington persisted for an unusually long time (two hours and thirty minutes); but, on the other hand, that part of the record embracing the maximum displacement of the recording pen was relatively of short duration. It is reproduced in fig. 1.
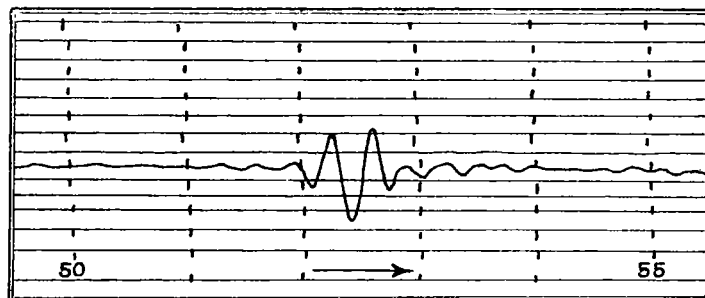

FIG. 1.—Maximum waves of Indian earthquake as recorded at Washington. Time correction +13 seconds.

The following table gives in detail the noticeable characteristics of the whole record.